Food safety problems of fresh produce in the U.S.

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The microbiological safety of fresh produce is an area of increasing concern in the U.S. The Centers for Disease Control reported 98 outbreaks of produce-related illnesses between 1990 and 1999, involving at least 6300 cases. It has been estimated that close to half of foodborne illnesses are probably attributable to produce. The majority of reported cases involved a limited number of commodities: alfalfa sprouts, lettuce or other salad greens, melons, tomatoes, apple cider, berries, cabbage, and unspecified fruits (including fruit cocktail). Where identified, the causative organisms included: *E. coli* O157:H7, *Salmonella* spp., *Shigella* spp., and *Cyclospora cayetanensis*. Human pathogens have been isolated from numerous fruits and vegetables (1).

In response to this problem, two major Federal programs were initiated in the U.S.: the President's Food Safety Initiative and the Produce and Imported Food Safety Initiative. Within the U.S. Department of Agriculture (USDA), the Agricultural Research Service (ARS) has allocated $6.6 million in 1999 to 8 projects in 4 locations on the microbiological safety of fresh produce. Related ARS research on manure management ($4.67M) is carried on at 5 locations. The U.S. Food & Drug Administration (FDA) is conducting similar research at 2 locations. USDA and FDA scientists are collaborating in research on the microbiological safety of unpasteurized apple cider and alfalfa sprouts.

Sources of microbial contamination. Fresh produce may become contaminated with human pathogens by direct contact with infected farm workers or food handlers. Workers must have access to adequate toilet and hand washing facilities and receive adequate training in hygiene and food safety. Produce contamination also may occur as a result of direct or indirect exposure to animal feces (cattle, deer, birds, amphibians), contaminated irrigation water, windblown dust, and improperly composted manure. Contamination may occur during harvesting if fruits that have fallen on the ground are taken, and if dirty bins are used. Water

used in drenchers, dump tanks and flumes in produce packing or processing plants also may be a source of contamination or means of cross-contamination. Water in contact with fresh produce should be potable and treated with sufficient chlorine, ozone, chlorine dioxide, or peroxyacetic acid to kill any human pathogens that may have been introduced. These sources of contamination can be avoided or mitigated by following Good Agricultural Practices and Good Manufacturing Practices, as specified in published guidelines for the produce industry.

Microbial attachment and state of microflora on produce. In studies with, apples, cantaloupe and alfalfa sprouts, we have seen that bacteria can rapidly attach to the commodity surface and resist removal by washing or treatment with anti-microbial agents (Table 1). Attachment may be to inaccessible sites such as cracks in the seed coat of alfalfa seeds, or the calyx or stem areas of an apple. These data demonstrate the resistance of *E. coli* within the stem and calyx areas to inactivation by 5% hydrogen peroxide (Table 2). Attachment may be enhanced by incorporation of bacteria into a biofilm that provides protection against detachment during washing and greater resistance to chemical anti-microbial agents. Human pathogens such as *Listeria monocytogenes*, *E. coli* O157:H7 and *Salmonella* are known to form biofilms. We have seen evidence of biofilm formation on growing sprouts and in punctures in inoculated apples. Bacteria may become internalized within the flesh of fresh produce by the process of temperature- or hydrostatic pressure-driven infiltration through pores, channels or wounds. Infiltration of tomatoes with *Salmonella* and of apples with *E. coli* O157:H7 has been demonstrated (2). There is some evidence that bacteria can be found within the flesh of fruits and vegetables, even where there is no obvious route of entry.

Microbial interactions favoring human pathogen growth. Human pathogens have been found in association with plant pathogens in areas of decay on fresh produce. In some cases, an antagonistic relationship may exist between decay organisms and human pathogens. Soft-rotting pseudomonads suppressed the growth of *L. monocytogenes* on inoculated potato slices (3). We are concerned that the removal of harmless antagonists by application of "too effective" anti-microbial washes might open up a niche for contaminating human pathogens and create a situation wherein a food becomes hazardous before the onset of obvious spoilage.

Interventions to improve microbiological safety. Research on the efficacy of washing treatments used for fresh produce has indicated that most conventional washing and sanitizing

agents may be effective in killing planktonic bacteria in process water but can only achieve a 1 or 2 log reduction (90-99%) in the bacterial population attached to the surface of fruits and vegetables (4). We have determined that log reductions for apples inoculated with a non-pathogenic *E. coli* and washed in a commercial brush washer were less than one, even when the washing agent was 200 ppm Cl_2 (pH 6.5) or 5% hydrogen peroxide, heated to 50°C (Table 3). Improvements in washing technology are required. Among the new approaches under consideration are surface pasteurization with hot water or steam, irradiation, use of novel anti-microbial agents, combinations of hurdles including the aforementioned treatments, use of competitive exclusion, and improved means of detecting produce defects that may be associated with human pathogen contamination.

At the present time, the most promising approach is the systematic identification of hazards in fresh produce packing and processing operations, and the development of procedures to control the process at vulnerable points in order to eliminate such hazards. This approach is referred to as a Hazard Analysis Critical Control Point (HACCP) plan. In the U.S., many processors are using GAP's, GMP's, and HACCP procedures or principles to ensure the microbiological safety of fresh produce.

Table 1—Attachment of *E. coli* (ATCC 25922) to apple surfaces

	$Log_{10}CFU/g^a$			
Time after	**4°C**		**20°C**	
inoculation	**Inoculated**	**After**	**Inoculated**	**After**
(hr)	**control**	**wash**	**control**	**wash**
0.5	**4.4±0.1**	**3.5±0.0**	**4.4±0.0**	**3.4±0.0**
24	**3.9±0.1**	**3.2±0.1**	**4.8±0.0**	**4.3±0.2**
48	**3.9±0.2**	**4.0±0.8**	**4.1±0.2**	**4.6±0.1**
72	**3.7±0.2**	**3.6±0.2**	**4.2±0.3**	**3.9±0.0**

[a]Mean of duplicate trials.

Table 2—Distribution of *E. coli* (ATCC 25922) on surface of inoculated apples before and after washing with 5% H_2O_2 at 50°C

	$Log_{10}(CFU/cm^2)$[a]	
Location	Inoculated	Washed[b]
Skin on wedges	5.14±0.03	1.88±0.88
Skin at calyx end of core	7.26±0.01	5.48±0.51
Skin on stem end of core	6.58±0.18	5.18±0.86

[a]Based on calculated surface area of skin; determined 24 h after inoculation.
[b]Washed 1 min in 5% H_2O_2 at 50°C.

Table 3. Decontamination of Inoculated Apples in a Flat-Bed Brush Washer

	E. coli ($log_{10}CFU/g$)[a]			
Treatment	Before Dump Tank	After Dump Tank	After Brush Washer	In Cider[b]
200 ppm Cl_2,	5.87±0.07	5.45±0.05	5.64±0.23	4.30±0.10
5% H_2O_2, 54°C	5.87±0.07	5.54±0.31	5.49±0.10	4.30±0.60

[a]Mean of 4 determinations ± SD.
[b]Log_{10} CFU/mL.

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